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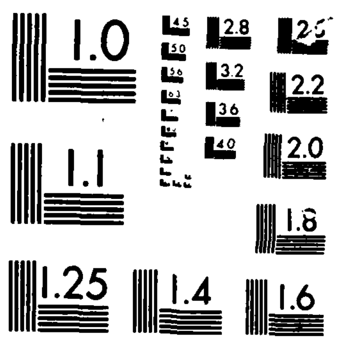
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AD-A168 978

WIND TUNNEL EVALUATION OF CHINOOK WT-11 ULTRA LIGHT

by

W.E.B. Roderick
National Aeronautical Establishment

AERONAUTICAL NOTE
NAE-AN-35
NRC NO. 25420

OTTAWA
FEBRUARY 1986

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WIND TUNNEL EVALUATION OF CHINOOK WT-11 ULTRA LIGHT

ESSAIS EN SOUFFLERIE DE L'AVION ULTRA-LÉGER CHINOOK WT-11

by/par

W.E.B. Roderick

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S.R.M. Sinclair, Head/Chef
Flight Research Laboratory/G.M. Lindberg
Laboratoire de recherche en vol

Director/Directeur

SUMMARY

Full scale wind tunnel tests were carried out on the wing and empennage of WT-11 Chinook ultra light aircraft in the NAE 9m X 9m Low Speed Wind Tunnel. This test program was initiated in response to a request from the Canadian Aviation Safety Board, Ottawa, Ontario to determine the aerodynamics of the vehicle and measure the gross structural airloads. The purpose of the test program was to establish if there were any unusual characteristics that might have contributed to several accidents involving this design.

Aside from considerable distortion of the wing at higher dynamic pressures, corresponding to 50 to 60 mph, and considerable aeroelastic effects on lift curve slope and maximum lift coefficient, at these higher dynamic pressures the basic wing does not appear to possess any inherently dangerous characteristics. However, the empennage exhibits some non-linear characteristics that could possibly cause handling qualities problems. The combination of wing stalling characteristics with horizontal tail characteristics could result in large amplitude pitch down at the stall.

RÉSUMÉ

Des essais en soufflerie à l'échelle réelle ont été menés avec l'aile et l'empennage de l'avion ultra-léger Chinook WT-11, dans la soufflerie à basse vitesse de 9 m X 9 m de l'EAN. Ce programme d'essais a été mis en oeuvre à la demande du Bureau canadien de la sécurité aérienne d'Ottawa (Ontario) dans le but de déterminer les caractéristiques aérodynamiques du véhicule et de mesurer les charges aérodynamiques structurelles brutes. Le programm visait à établir si des caractéristiques inhabituelles pouvaient avoir contribué à plusieurs accidents survenus avec cet avion.

À part une distorsion considérable de l'aile à des pressions dynamiques élevées, correspondant à 50 — 60 mph, et des effets aéroélastiques considérables sur la pente de la courbe de sustentation et sur le coefficient de sustentation maximum, à ces pressions dynamiques élevées, l'aile de base ne semble pas posséder de caractéristiques naturellement dangereuses. Par contre l'empennage présente certaines caractéristiques non linéaires qui pourraient causer des problèmes de pilotage. La combinaison des caractéristiques de décrochage de l'aile et des caractéristiques de l'empennage horizontal pourrait entraîner un tangage de grande amplitude au décrochage.

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ILLUSTRATIONS (Cont'd)

WIND TUNNEL EVALUATION OF CHINOOK WT-11 ULTRA LIGHT

1.0 INTRODUCTION

As a result of two fatal accidents involving Chinook WT-11 ultra light aircraft the Aviation Safety Board approached the National Aeronautical Establishment with a request for a wind tunnel test of the vehicle. The test was carried out in the NAE 9m X 9m Low Speed Wind Tunnel, Reference 1.

Birdman Enterprises of Edmonton, Alberta the manufacturer supplied a wing kit and a new assembled empennage. In addition a slightly damaged empennage salvaged from one of the accidents was available for test. The wing was assembled in accordance with the enclosed instructions by personnel of the Aviation Safety Board.

The Low Speed Aerodynamics Laboratory installed the components in the wind tunnel and operated the system for the test.

The Flight Research Laboratory of NAE supervised the program at the request of the Aviation Safety Board. The general aerodynamic characteristics, torsional stability, flutter characteristics and aerofoil profile changes of the wing as a function of airspeed were assessed. The horizontal tail aerodynamic characteristics were also documented. In addition the effects of damage, loose fabric and torn fabric on the tail performance were investigated.

The tests were also video taped. This was done with voice over identification of tunnel parameters and test configuration. The video tapes are currently held by the Aviation Safety Board, Ottawa, Ontario.

The wind tunnel test program was carried out in the first two weeks of May 1985. The actual test runs required six days with an additional three days for installation and set-up.

2.0 DESCRIPTION OF VEHICLE

The WT-11 Chinook is a high-wing strut-braced monoplane in a single engine pusher configuration. The construction is primarily light gauge aluminum tubing riveted and bolted together with Dacron wing and empennage covering. The vehicle specifications are listed in Table 1 and the geometry is illustrated in Figure 1.

The wing airfoil is based on the UA81/2 18% High Lift Wing developed at the University of Alberta. The coordinates are listed in Table 2 and plotted in Figure 2. The results of wind tunnel airfoil tests carried out at the University of Alberta are shown in Figures 3 through 5. The airfoil as used in the WT-11 Chinook has a trailing edge extension that basically follows the upper surface contour and increases the chord approximately six inches, (Fig. 2). This airfoil is designated UA81-M.

3.0 WIND TUNNEL TEST PROGRAM

The wind tunnel test program was carried out in two phases. For the first phase a wing was mounted on the tunnel turntable as a reflection plane model.

This wing was tested over a range of dynamic pressures and a range of angle of attack from near zero lift coefficient to the stall. The configurations tested were, aileron fixed at zero incidence, then full down, full up and a final sequence with the aileron free to float.

In the second phase a complete empennage assembly was mounted on a sting initially rolled 90° so that rotation of the tunnel table represented angle of attack changes. The empennage was then rolled upright so that tunnel table rotation represented yaw.

In this second phase two complete units were used, a new unit and then a second unit which had been involved in an accident. The fabric of the second unit was loose and a deliberate leading edge rip was tested at two lengths to establish the effect of covering damage on horizontal tail aerodynamics.

The sequence and configurations of wing and empennage tests are given in Reference 2 and reproduced in Table 3 and Table 4 of this report.

4.0 RESULTS

The data acquisition system of the 30 foot wind tunnel prints out non-dimensional coefficients based on model geometry and measured parameters. Angle of attack was measured at the wing root relative to the line passing through the front and rear spars. A typical print out, in this case Run 36 of Table 3 from Reference 2, is shown in Table 5 and the associated plot of C_L vs α is reproduced in Figure 6.

The test results reported here gave maximum lift coefficients only two thirds the values obtained by the University of Alberta tests, illustrated in Figure 3.

As dynamic pressure was increased with aileron fixed neutral, zero degrees deflection, the wing twisted quite noticeably. Near the root incidence of 8 degrees for higher dynamic pressures there was considerable buffeting. The slope of the lift curve decreased with increasing dynamic pressure and so did the maximum lift coefficient.

The lift coefficient versus angle of attack, with aileron fixed neutral, for dynamic pressures from 2.3 to 10.8 pounds per square foot, are shown in Figure 7.

In Figure 8 with the aileron fixed full up the reduction in pitching moment is obvious and there is a slight decrease in lift curve slope with dynamic pressures from 2.3 to 4.1 pounds per square foot. In Figure 9, with the aileron free to float, over the same dynamic pressure range the effects of wing flexibility become more obvious.

In Figure 10 with aileron fixed full down the maximum lift coefficient at $\alpha = 8^\circ$ is, as expected, higher than the other cases. However, the change in maximum value and the change in slope with dynamic pressure are greater then the other cases. With aileron down the decrease in maximum lift coefficient at $\alpha = 8^\circ$ with an increase of dynamic pressure from 2.3 to 4.1 pounds per square foot is 1.1. The same increments for aileron zero and full up are respectively a decrease of 0.8 and 0.55. The maximum value of lift coefficient was marginally greater then the value at $\alpha = 8^\circ$ but the lift curve slope is almost horizontal beyond $\alpha = 8^\circ$ as illustrated in Figure 6 for all wing tests.

The results of the empennage test show marked non linear stall characteristics for angles of attack of opposite sign to elevator deflection, that is, trailing edge down and leading edge up, or trailing edge up and leading edge down.

Since the stabilizer tapers to zero chord at the tip while the elevator has constant chord, the theoretical effect is a change in incidence at the tip equal to the elevator deflection while the centre line increment is approximately 70% of the elevator deflection (Fig. 11).

The result is a large apparent wash-in and at the stall a maximum empennage lift coefficient that actually appears to decrease with increasing elevator deflection (Fig. 12).

A single asymmetric sweep in yaw was carried out from -10° to $+20^\circ$ with rudder and elevator both at zero deflection. The results showed some scatter but were essentially linear (Fig. 13).

The final test runs were carried out on an empennage salvaged from an accident. The fabric was not as taut as that of the initial test specimen, but the lift curve slope was unchanged and values of aerodynamic coefficients were within ten percent of the first tests (Fig. 14).

The fabric on the horizontal stabilizer was then cut along the lower surface leading edge on the starborad side, for approximately six inches. The angle of attack was swept from $-8°$ to $+8°$ fuselage attitude. The cut was then extended for approximately two thirds of the semi-span and the angle of attack was swept from $-10°$ to $+16°$. The lift curves against angle of attack are compared with the uncut tailplane in Figure 15.

5.0 DISCUSSION OF RESULTS

The deformation of the wing with increasing dynamic pressure was immediately apparent. In comparison with conventional aircraft structure such deflections are unusually large. However despite the large torsional deformation at the higher dynamic pressures, with aileron deflected trailing edge down, and considerable buffeting there was no divergence or any structural failure.

There is an obvious break in the lift curves around 8 degrees angle of attack. This was typical of all the wing tests. The apparent initial wing stall at all dynamic pressures seemed to occur at a root chord incidence of 8 degrees, indicating a root separation problem.

The maximum lift coefficient at $\alpha = 8°$ and the slope of the lift curves were very sensitive to changes in dynamic pressure and aileron deflection. The sensitivity and reduction in performance was probably due to the deflection of the airframe under load and distortion of the airfoil because of compliance of the fabric covering. Figures 7, 8, 9 and 10 illustrate this phenomenon. Not so obvious is the effect on wing aerodynamic efficiency. In Figure 16 the considerable variation of maximum lift to drag ratio with dynamic pressure is illustrated.

To assess analytically the performance of this vehicle would require considerable cross plotting to evaluate a specific wing loading, lift coefficient, and dynamic pressure using the available tunnel test data.

The wing shows a lift curve slope break, for all configurations, when the root chord approaches eight degrees. Since the high camber and lack of torsional rigidity result in considerable wash out at the wing tip, the stall would appear to initiate at the root. This will result in a dramatic change in the spanwise down-wash distribution behind the wing. Specifically the horizontal tail can be expected to experience a sudden decrease in down wash.

There is no decrease in wing negative pitching moment at the stall and thus the horizontal tail must be capable of generating sudden incremental variations in loading to maintain control.

The comparison with the test results on the UA 81/2 (Fig. 3) and the wing (Fig. 6) show a marked difference in stalling characteristics and maximum lift coefficient. Part of the difference can be explained by three-dimensional effects but the major discrepancies are probably due to poor profile definition as a result of the method of fabrication. Fabric covered wings are not suitable for controlled chordwise pressure distribution airfoils. The lack of precise profile definition defeats the designer's best efforts.

As a result of the method of measuring forces and moments in the 9m X 9m Low Speed Wind Tunnel the following explanation is required for empennage test results: any change in incidence or control deflection that results in a nose up pitching moment is considered positive. Elevator trailing edge up or horizontal stabilizer leading edge down would, for the purpose of this report, be considered positive.

For the one yaw case tested the data was reduced using horizontal tail plane area as the reference area. The effective lift coefficients should be larger by an approximate factor of two but are not of critical interest (Fig. 13).

One point that is of interest in the geometry of the horizontal tail plane. Since the horizontal stabilizer tapers to zero at the tip and the elevator has constant chord an effective positive spanwise twist is produced by an elevator deflection increasing the effective lift coefficient. This indicates that elevator deflections, adding to tail load produced by incidence, will result in wash-in and tip stall (Fig. 11). This is inherent in this empennage geometry.

The effect of the wash-in on the horizontal tail is to limit the maximum lift coefficient. When incidence and elevator deflection combine to increase effective lift coefficient the values collapse at the stall and effectively limit the horizontal tail control power (Fig. 12).

The comparison of a new and a damaged empennage indicate no change in lift curve slope and aside from the stall the differences can be ascribed to the accuracy of installation in the wind tunnel. The new empennage achieves a slightly higher lift coefficient but has a more violent stall (Fig. 14).

Cutting the empennage fabric covering along the leading edge, on the lower surface of the horizontal stabilizer, resulted in a sudden ballooning of the lower surface covering when the effective angle of attack resulted in suction on the lower surface leading edge. The initial six inch cut on one side near the tip resulted in an effective camber change, when the fabric ballooned, equivalent to approximately five degrees of up elevator.

Extending the cut to twenty-four inches resulted in a similar trend but the damage reduced the effective camber change and tended to destroy the flow. The longer cut was only half as effective as the initial six inch cut (Fig. 15). This single test demonstrates that the nature and extent of any damage can be quite critical to horizontal tail effectiveness and can have large effects on longitudinal stability.

Damage to the lower surface could result in pitch up and conversely damage to the upper surface could result in pitch down.

6.0 CONCLUSIONS

Because of the flight safety implications of any problem areas with flexible non-linear aircraft such as the WT-11 Chinook there are several areas that should be investigated in more depth. For example, the horizontal tail characteristics should be studied in more detail and their effects on gross handling characteristics should be investigated.

Since the vehicle is too large for full scale testing in any Canadian wind tunnel the possibility of a short flight test program should be considered to establish neutral points and to evaluate stall characteristics and power effects on longitudinal handling qualities.

At the present time there is virtually no flight test data on this class of vehicles.

7.0 REFERENCES

1. *The 9m V/STOL Wind Tunnel.*
A Brief Description and Photographic Review of Projects.
National Research Council, Ottawa. July 1979.

2. *WT-11 Chinook Test.*
National Research Council 9m × 9m Wind Tunnel Data Report 30/2073.

TABLE I

WT-11 SPECIFICATION

Airframe	Empty weight	250 lbs
	Wingspan	35 ft
	Wing Area	140 sq ft
	Height	5 ft 6 in
	Length	17 ft 6 in
	Fuel capacity	5 gal
	Seats	One
	Construction	Aluminum, Dacron
	Portability	Trailer
	Set-up time	15 minutes, two persons
Powerplant	Engine	Rotax 277
	Output	28 hp @ 6,000 rpm
	Thrust	175 lbs
	Drive type	V belt
	Propeller	50 x 30 wood
Performance	Staff	25 mph
	Cruise	55 mph
	Top Speed	63 mph
	Vne	90 mph
	Gross weight	625 lbs
	Design load factor	+6 - 3 Gs
	Climb rate	750 fpm @ 37 mph
	Glide ratio	10 to 1
	Wing loading	4.46 lbs/sq ft
	Power loading	22.32 lbs/hp
	Field requirements	Short field
Information	Manufacturer's address	Birdman Enterprises 7939 Argyll Road Edmonton, Alberta Canada, T6C 4A9 (403) 466-5370

TABLE 2

UA 81/2 18% High Lift Airfoil Coordinates

Ref.	X/C	Y_U/C	Y_L/C
1	0.00000	0.00000	0.00000
2	0.00293	0.01267	-0.00647
3	0.01169	0.03087	-0.01155
4	0.02617	0.04917	-0.01553
5	0.04621	0.06944	-0.01850
6	0.07157	0.08844	-0.02075
7	0.10195	0.10740	-0.02201
8	0.13700	0.12339	-0.02310
9	0.17631	0.13731	-0.02320
10	0.21941	0.14735	-0.02329
11	0.26580	0.15540	-0.02256
12	0.31493	0.15929	-0.02196
13	0.36624	0.16039	-0.02065
14	0.41911	0.15593	-0.01950
15	0.47293	0.14577	-0.01793
16	0.52707	0.13160	-0.01660
17	0.58089	0.11821	-0.01474
18	0.63376	0.10395	-0.01334
19	0.68507	0.09062	-0.01149
20	0.73420	0.07579	-0.01013
21	0.78059	0.06232	-0.00835
22	0.82369	0.04995	-0.00708
23	0.86300	0.03857	-0.00544
24	0.89805	0.02862	-0.00437
25	0.92843	0.01957	-0.00303
26	0.95379	0.01287	-0.00224
27	0.97383	0.00700	-0.00112
28	0.98831	0.00299	-0.00062
29	0.99707	0.00083	0.00000
30	1.00000	0.00000	0.00000

TABLE 3

WT-11 CHINOOK HALF WING

RUN LOG SHEET TEST NO. 2073

	DATE	RUN NO.	PITCH ANGLE	WING SPEED	REMARKS
1	1/5/85	30	- 6° to 20°	20 MPH	Aileron fixed at zero
2		32		24 MPH	
3		34		30 MPH	
4		36		36 MPH	
5		38		40 MPH	
6		40	-10° to 20°	24 MPH	Aileron fixed full downward
7		42		30 MPH	
8		44		36 MPH	
9		46		40 MPH	
10		48		24 MPH	Aileron fixed full upward
11		50	- 8 to 20°	30 MPH	
12		52		36 MPH	
13		54	- 6 to 20°	40 MPH	
14	2/5/85	56	- 8 to 20°	20 MPH	Aileron free
15		58		30 MPH	
16		60		36 MPH	
17		62		40 MPH	
18		64	- 4° to 4°	55 MPH	Aileron fixed at zero
19		66	- 4° to 8°	55 MPH	
20		68	- 4° to 20°	55 MPH	
21		70	- 2° to 14°	65 MPH	

TABLE 4

WT-11 CHINOOK TAIL TEST

RUN LOG SHEET TEST NO. 2073

	RUN	TARE	V_{mph}	δ_R	δ_{RANGE}	δ_r	β_{RANGE}		
07/05/85	73	- 72	25	0°	- 8, +20	0°	0°		
	74	- 72	30	0°	- 8, +20	0°	0°		
	75	- 72	36	0°	- 8, +20	0°	0°		
	76	- 72	40	0°	- 8, +20	0°	0°		
08/05/85	79	- 78	45	0°	-12, +20	0°	0°		
	81	- 78	40	5°	-12, +20	0°	0°		
	82	- 78	30	5°	-12, +20	0°	0°		
	84	- 78	30	10°	-12, +20	0°	0°		
	86	- 78	40	10°	-12/+20/-12	0°	0°		
09/05/85	88	- 78	30	15°	-10, +20	0°	0°		
	89	- 78	40	15°	-10, +20	0°	0°		
	91	- 78	30	20°	-10, +20	0°	0°		
	92	- 78	40	20°	-10, +20	0°	0°		
	93	- 78	30	- 5°	-10, +20	0°	0°		
	94	- 78	40	- 5°	-10, +20	0°	0°		
	96	- 78	30	-10°	-10, +20	0°	0°		
	97	- 78	40	-10°	-10, +20	0°	0°		
	99	- 78	30	-15°	-10, +20	0°	0°		
	100	- 78	40	-15°	-10, +20	0°	0°		
	102	- 78	40	0°	0°	0°	-10, +20		
10/05/85	104	-103	40	0°	-10, +20	0°	0°	Yellow tail	
	106	-103	40	10°	-10, +20	0°	0°	Yellow tail	
	107	-103	30	0°	- 8, + 8	0°	0°	Yellow tail	6" Rip Bottom
	108	-103	40	0°	-10, +16	0°	0°	Yellow tail	2/3 L.E. Starboard

TABLE 5

NRC 30 Foot Wind Tunnel
Transport Canada Aviation Safety Investigation
WT-11 Chinook

Report No.: 2073

Date: 01-MAY-85 Time: 10:38:20 Averaging- Digital (in sec) 5 Analog (samples) 5

Run No. 36 Tare No. -23 Ref. Tare No. -35 Pressure 100.72

Basic Coefficients

Pt	Q	Vel	Alpha	CL	CD	CM	CY	Cn	Cl	K	Temp.
1	3.339	36.0	0.00	0.630	0.065	-0.145	-0.001	-0.022	-0.202	1.012	284.8
2	3.358	36.2	-6.05	0.040	0.064	-0.126	0.009	-0.021	-0.017	1.014	285.0
3	3.358	36.2	-4.02	0.239	0.059	-0.144	0.002	-0.019	-0.078	1.013	285.0
4	3.355	36.1	-1.97	0.440	0.060	-0.144	-0.002	-0.019	-0.142	1.012	285.1
5	3.337	36.1	4.13	0.986	0.084	-0.144	-0.020	-0.026	-0.313	1.011	285.1
6	3.358	36.2	8.12	1.191	0.131	-0.150	-0.007	-0.043	-0.376	1.017	285.2
7	3.394	36.4	12.02	1.234	0.187	-0.160	-0.016	-0.061	-0.383	1.028	285.2
8	3.410	36.5	14.01	1.278	0.215	-0.154	-0.029	-0.068	-0.396	1.033	285.2
9	3.429	36.6	16.01	1.272	0.242	-0.159	-0.034	-0.076	-0.390	1.039	285.4
10	3.443	36.6	18.02	1.272	0.271	-0.147	-0.032	-0.086	-0.388	1.045	285.4
11	3.452	36.7	20.02	1.250	0.301	-0.157	-0.036	-0.095	-0.377	1.053	285.4

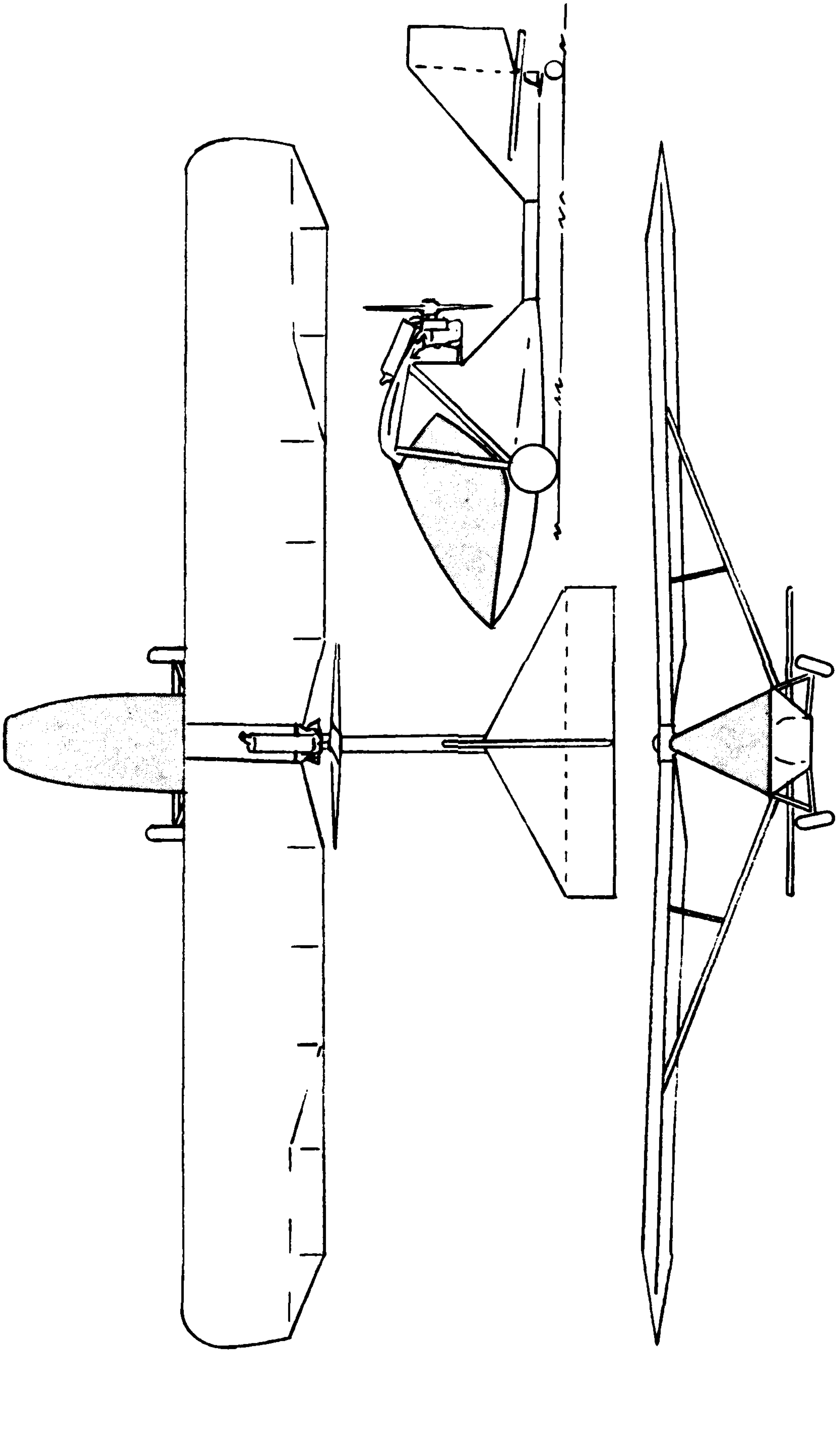

FIG. 1: WT-11 GEOMETRY

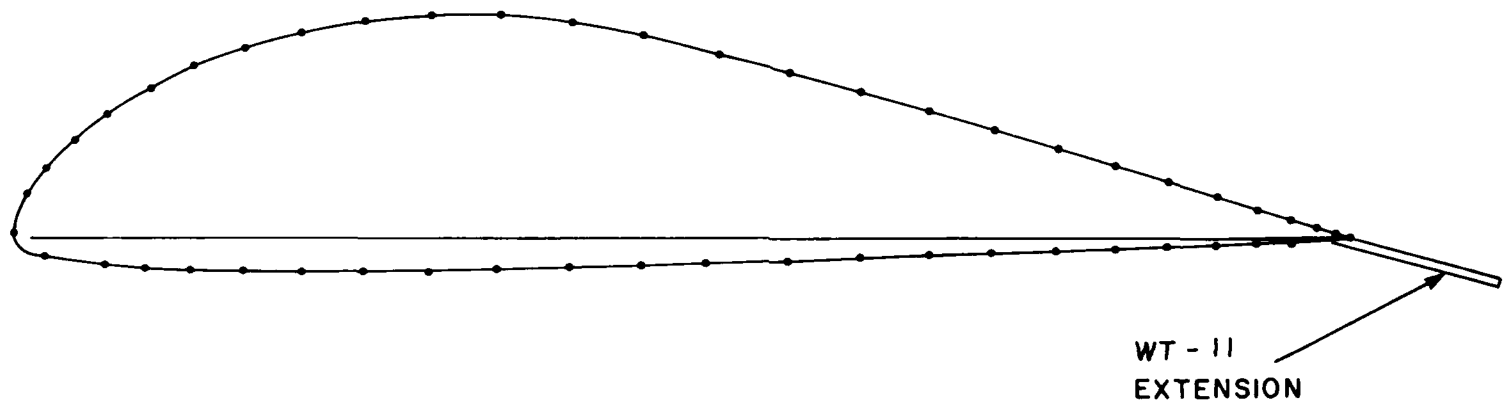

FIG. 2: UA 81/2 18% HIGH LIFT SECTION

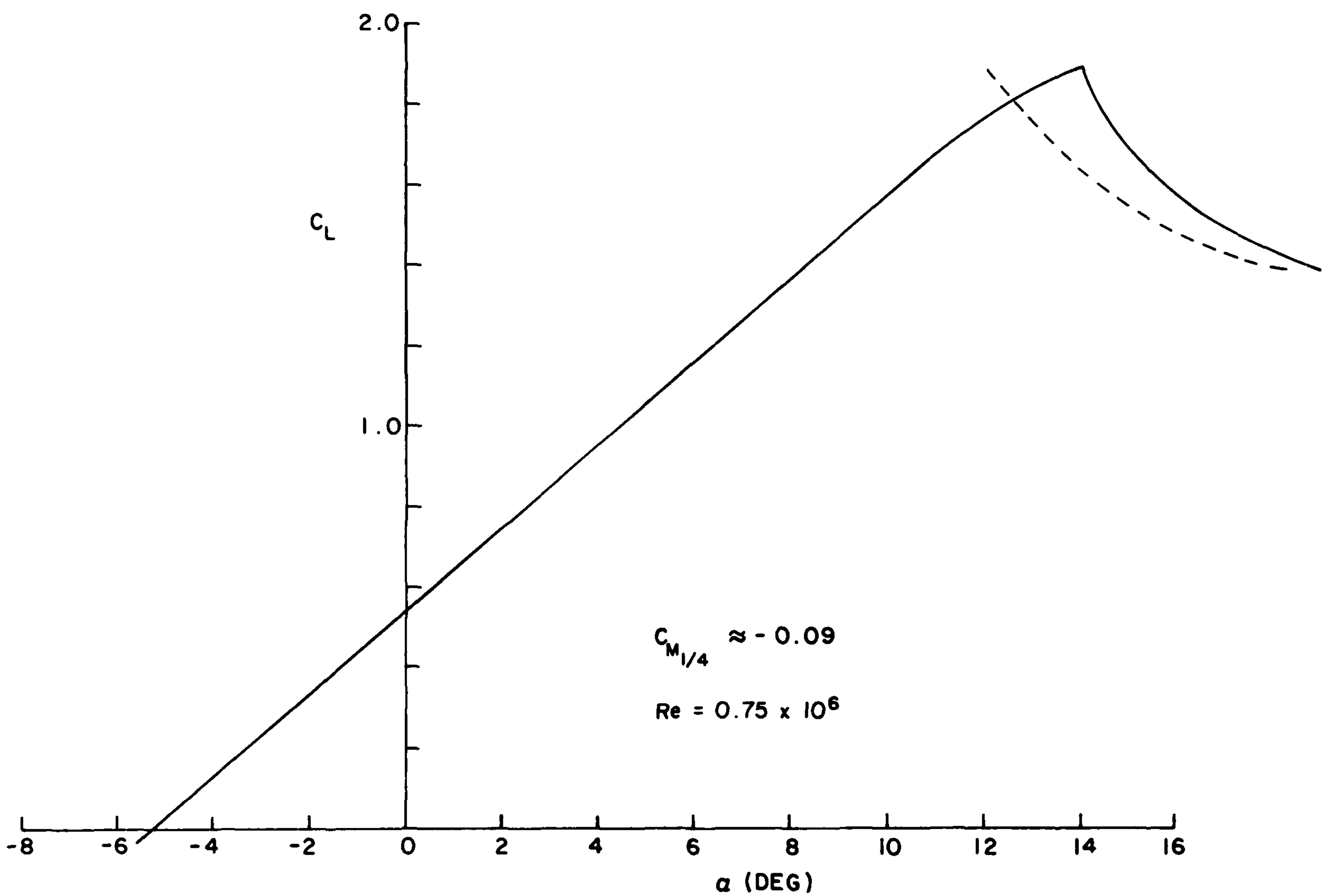

FIG. 3: UA 81/2 C_L VERSUS α

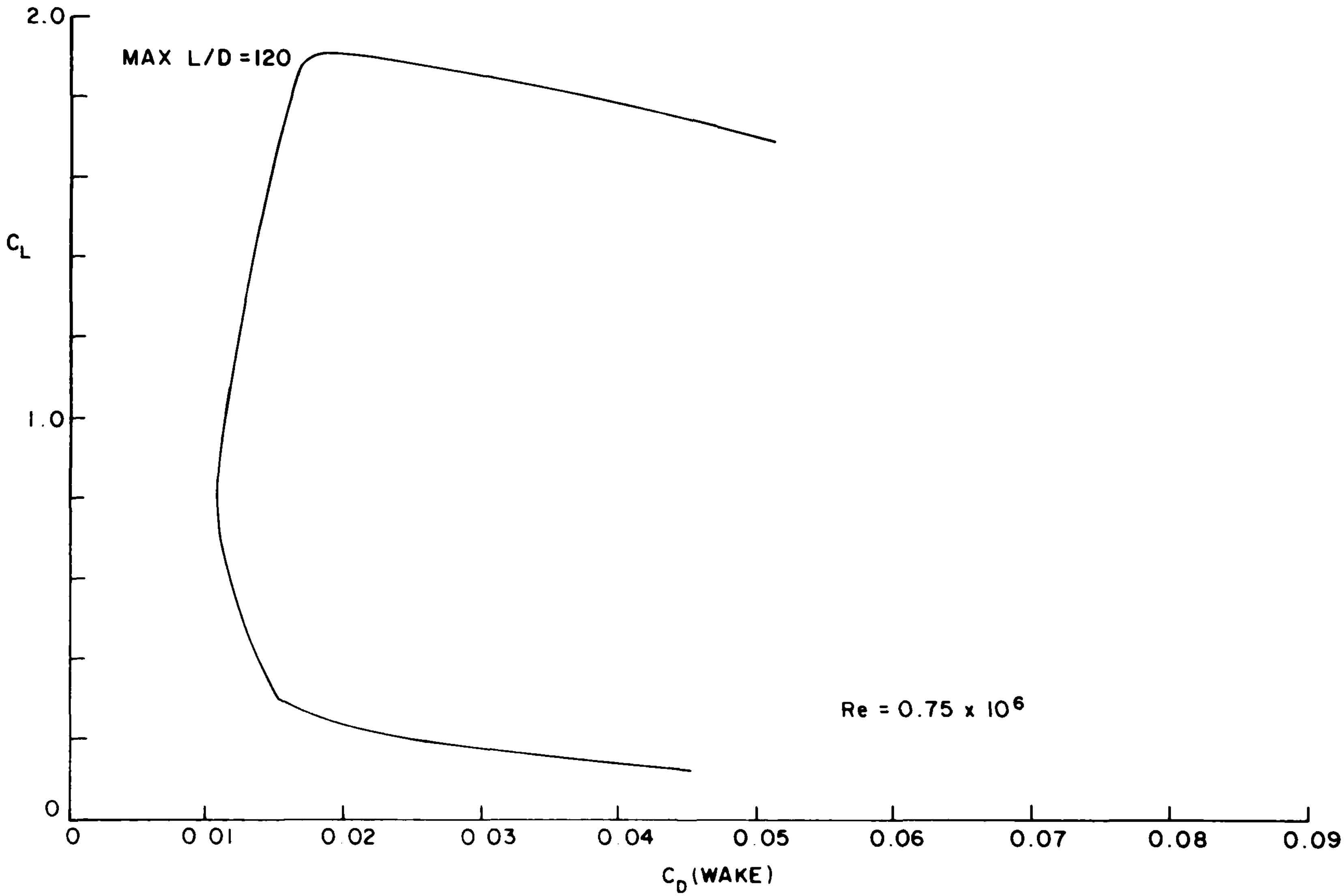

FIG. 4: UA 81/2 C_L VERSUS C_D

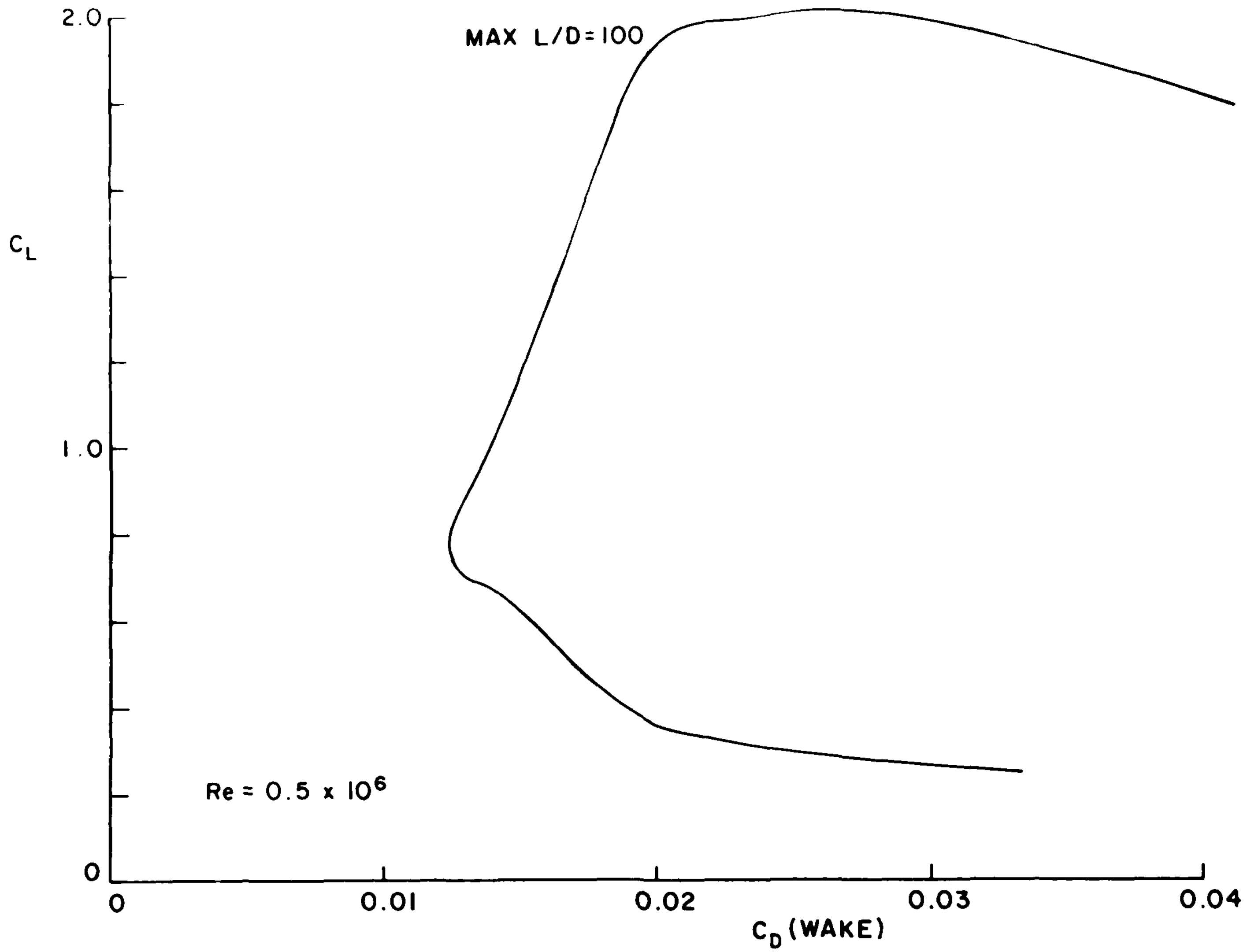

FIG. 5: UA 81/2 C_L VERSUS C_D

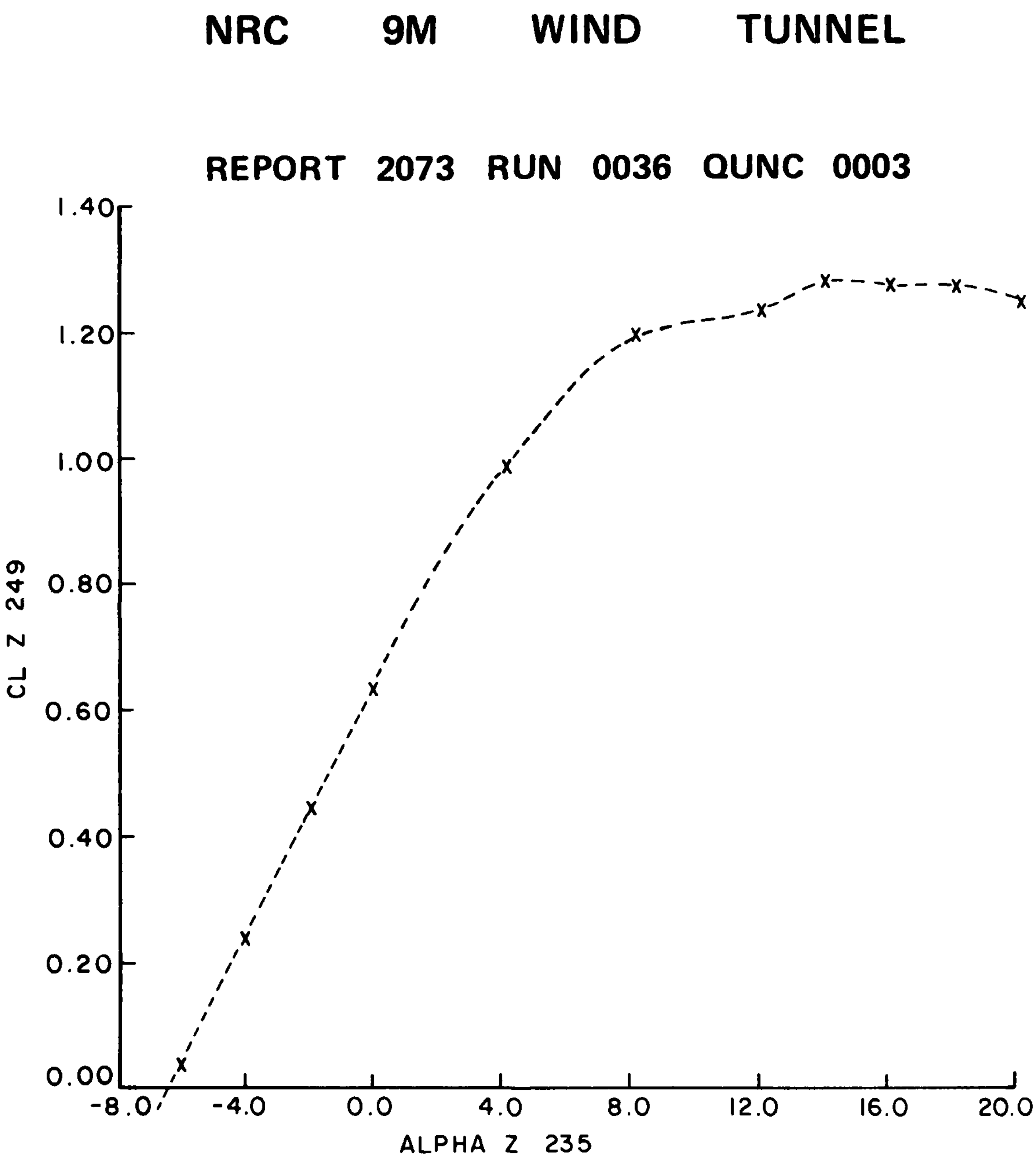

FIG. 6: 9m X 9m TUNNEL PRINTOUT AND C_L VERSUS α CURVE

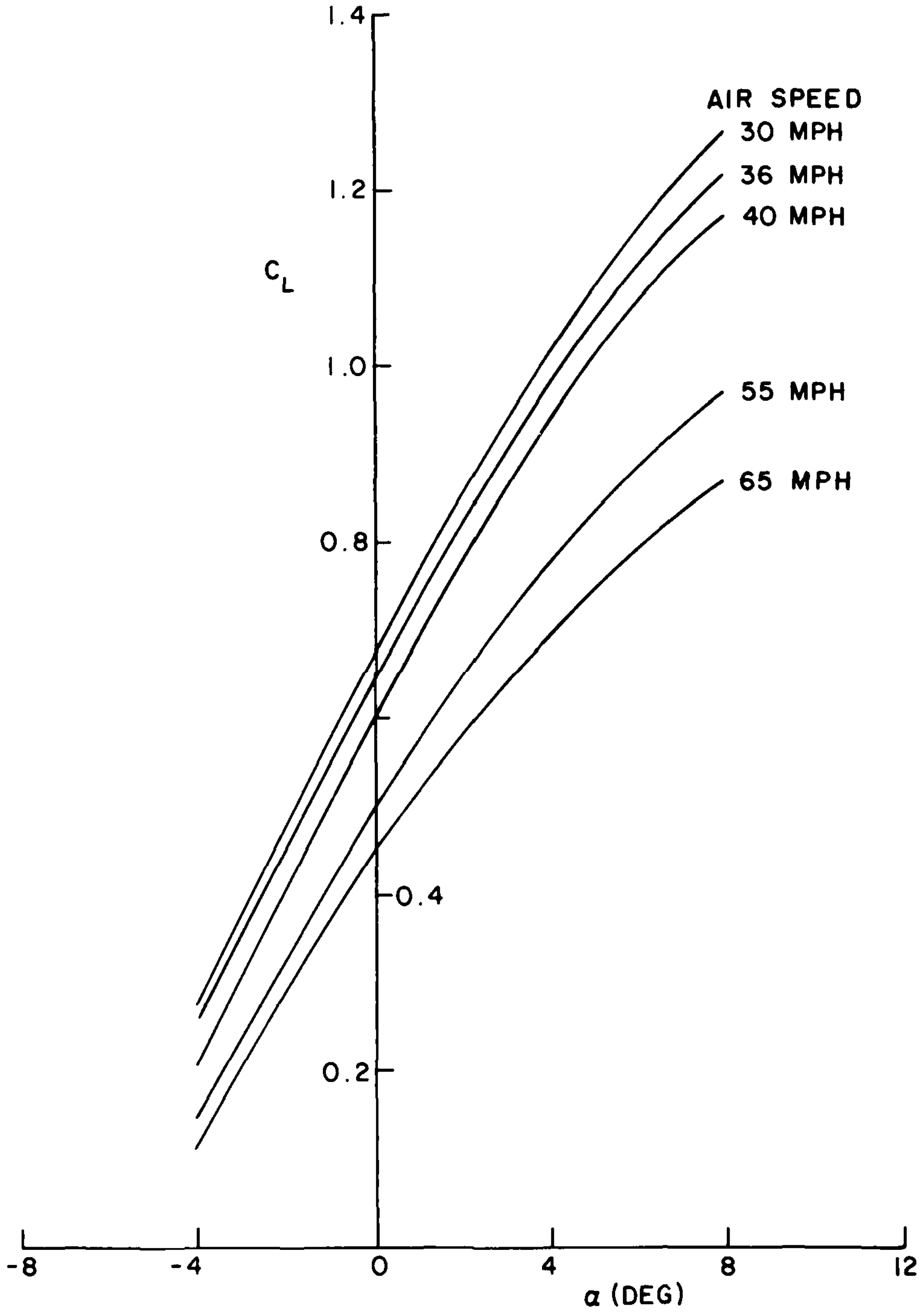

FIG. 7: C_L VERSUS α FOR VARYING q, $\delta_a = 0°$

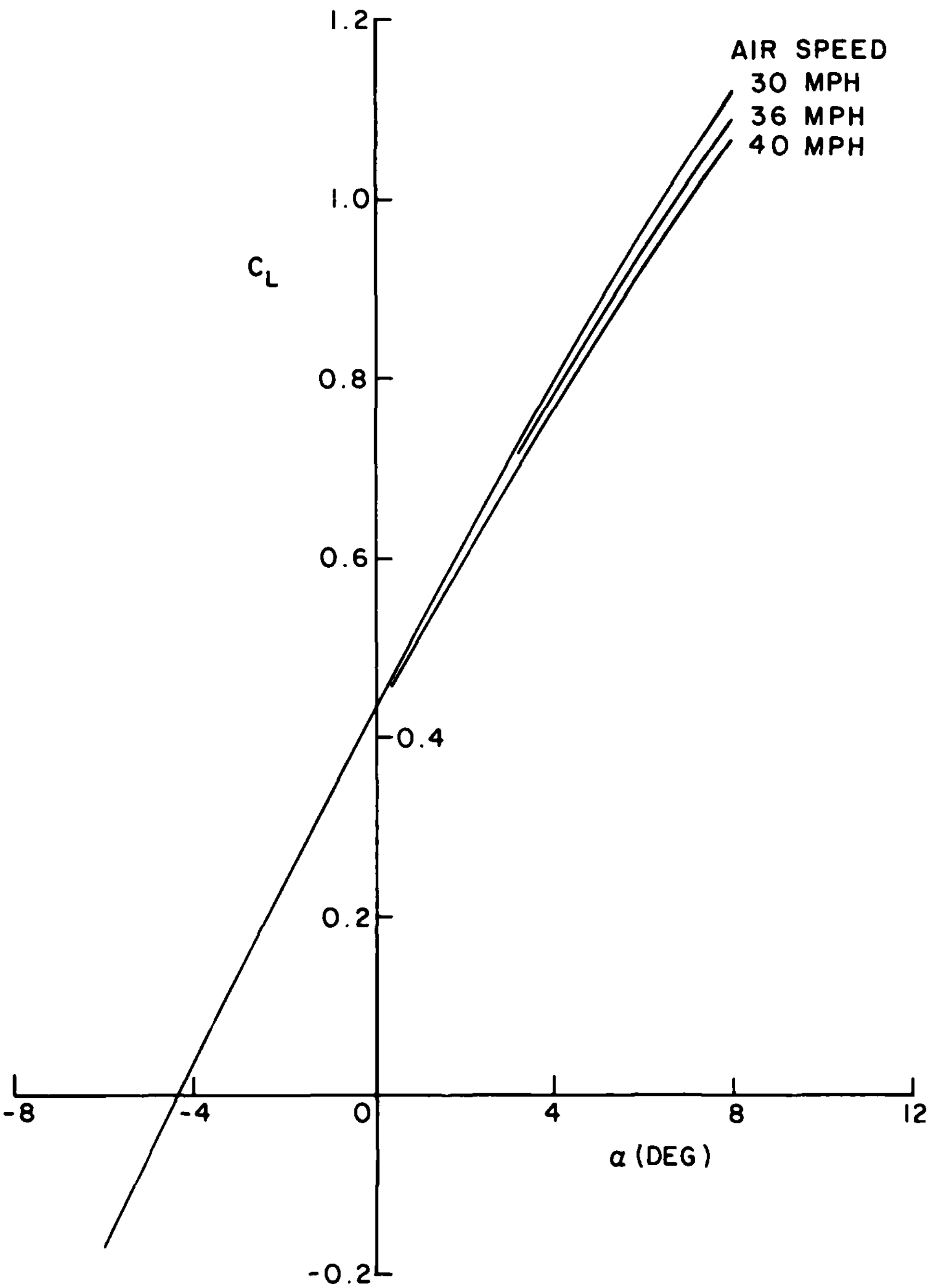

FIG. 8: C_L VERSUS α FOR VARYING q, δ_e MAXIMUM NEGATIVE VALUE

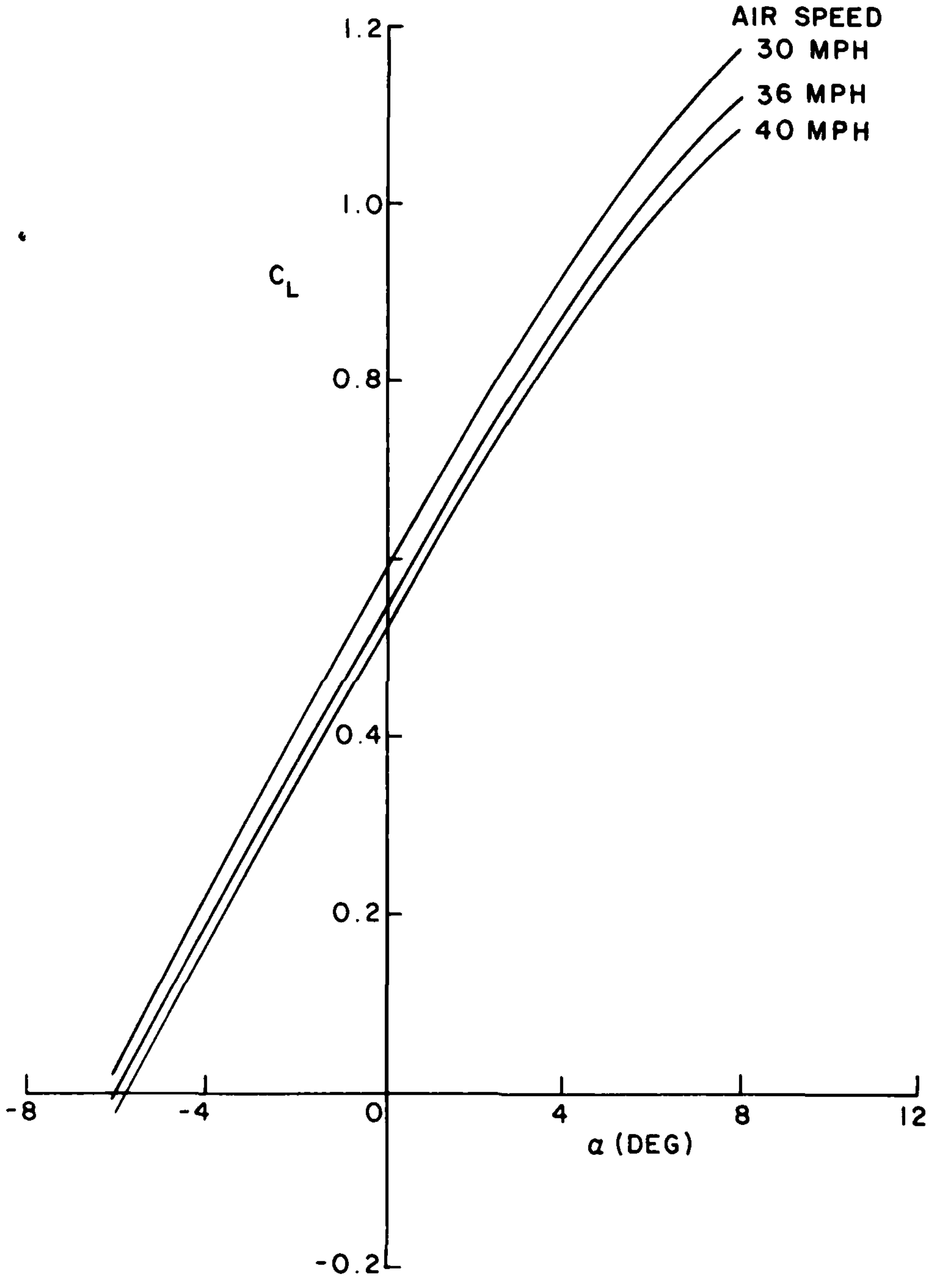

FIG. 9: C_L VERSUS α FOR VARYING q, δ_e FREE

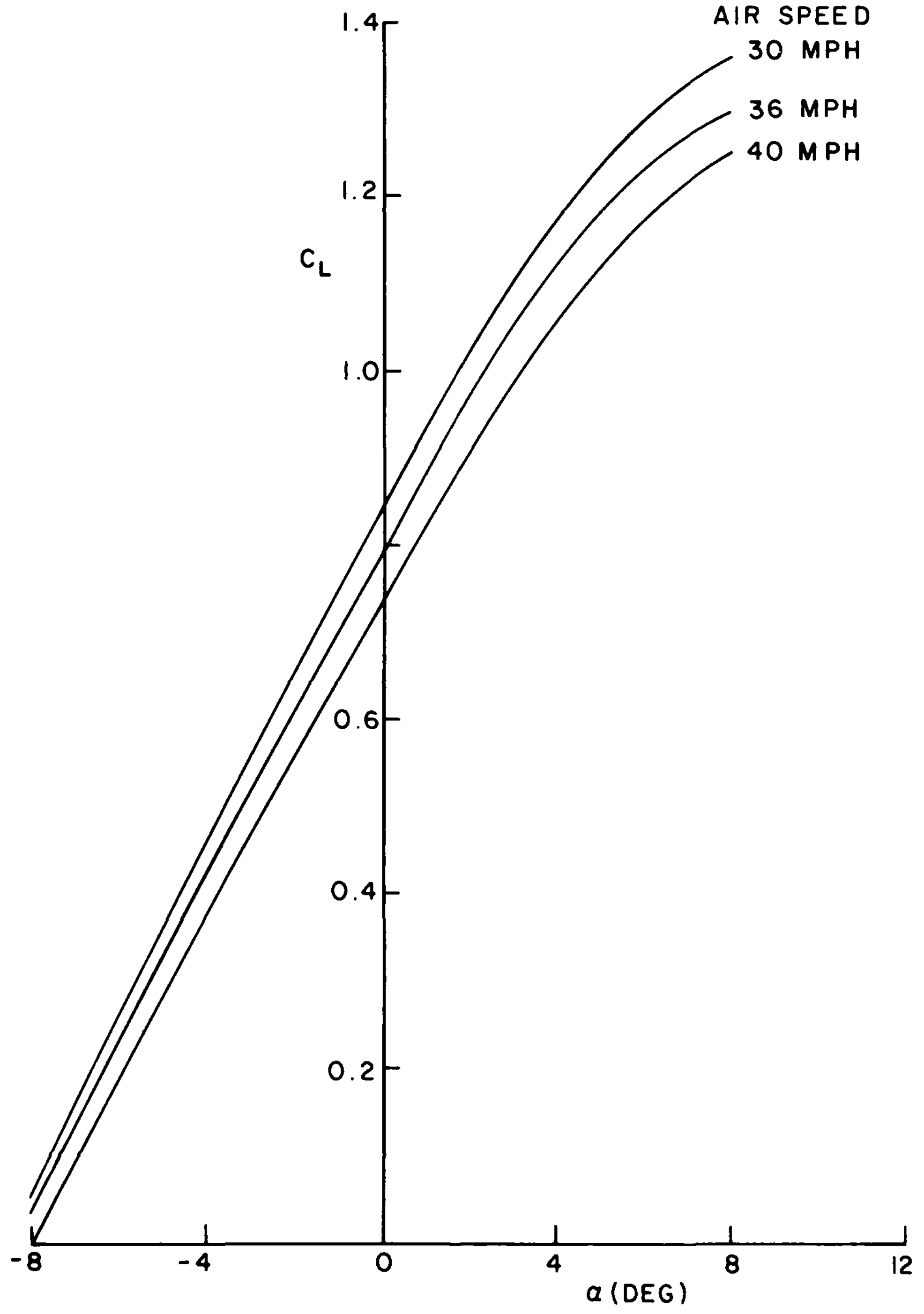

FIG. 10: C_L VERSUS α FOR VARYING q, δ_a MAXIMUM POSITIVE VALUE

WT-11 HORIZONTAL STABILIZER
THEORETICAL SPANWISE CONTROL EFFECTIVENESS

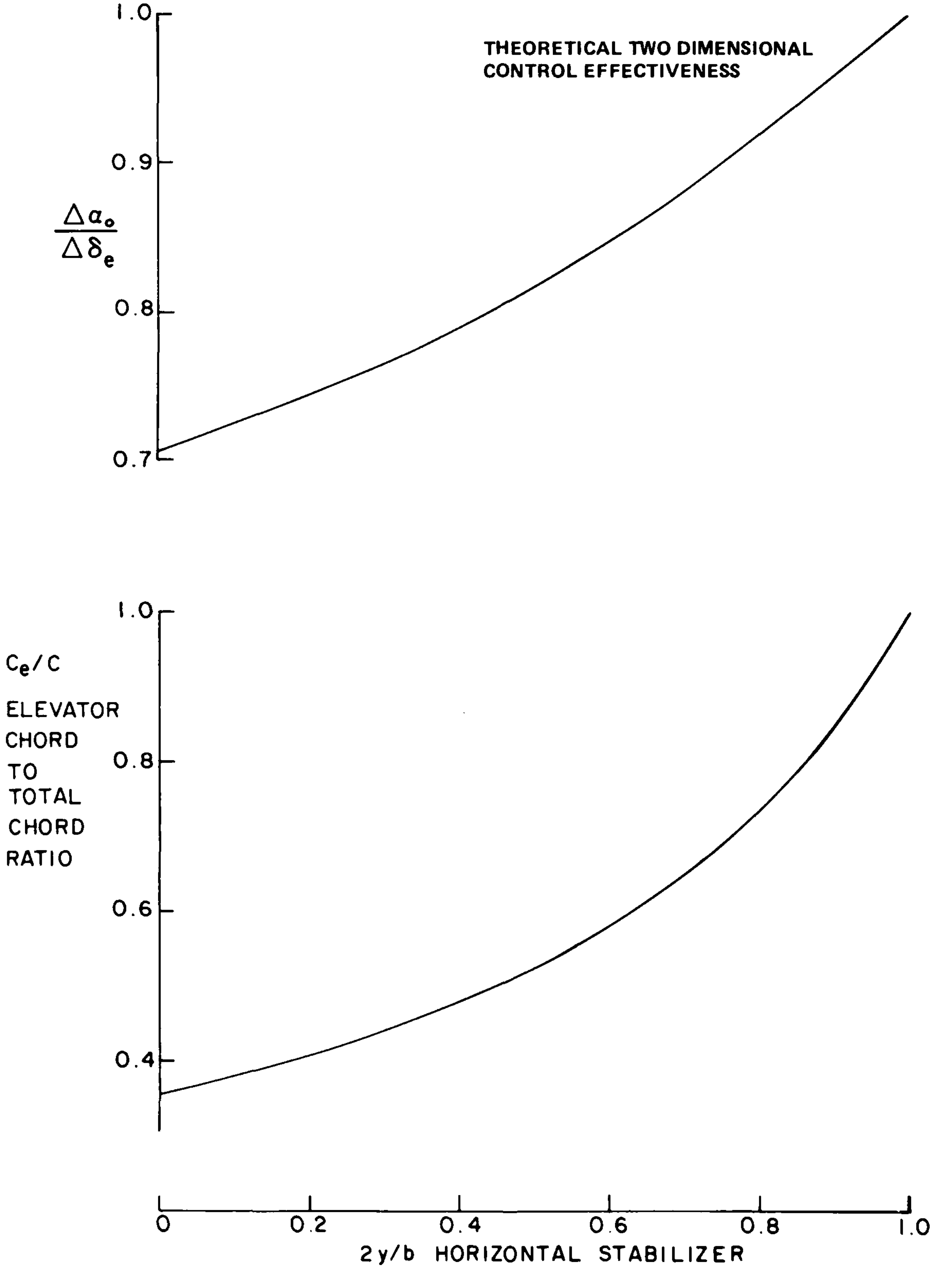

FIG. 11: THEORETICAL $\Delta\alpha^\circ$ VERSUS $\Delta\delta_e$ FOR WT-11 EMPENNAGE

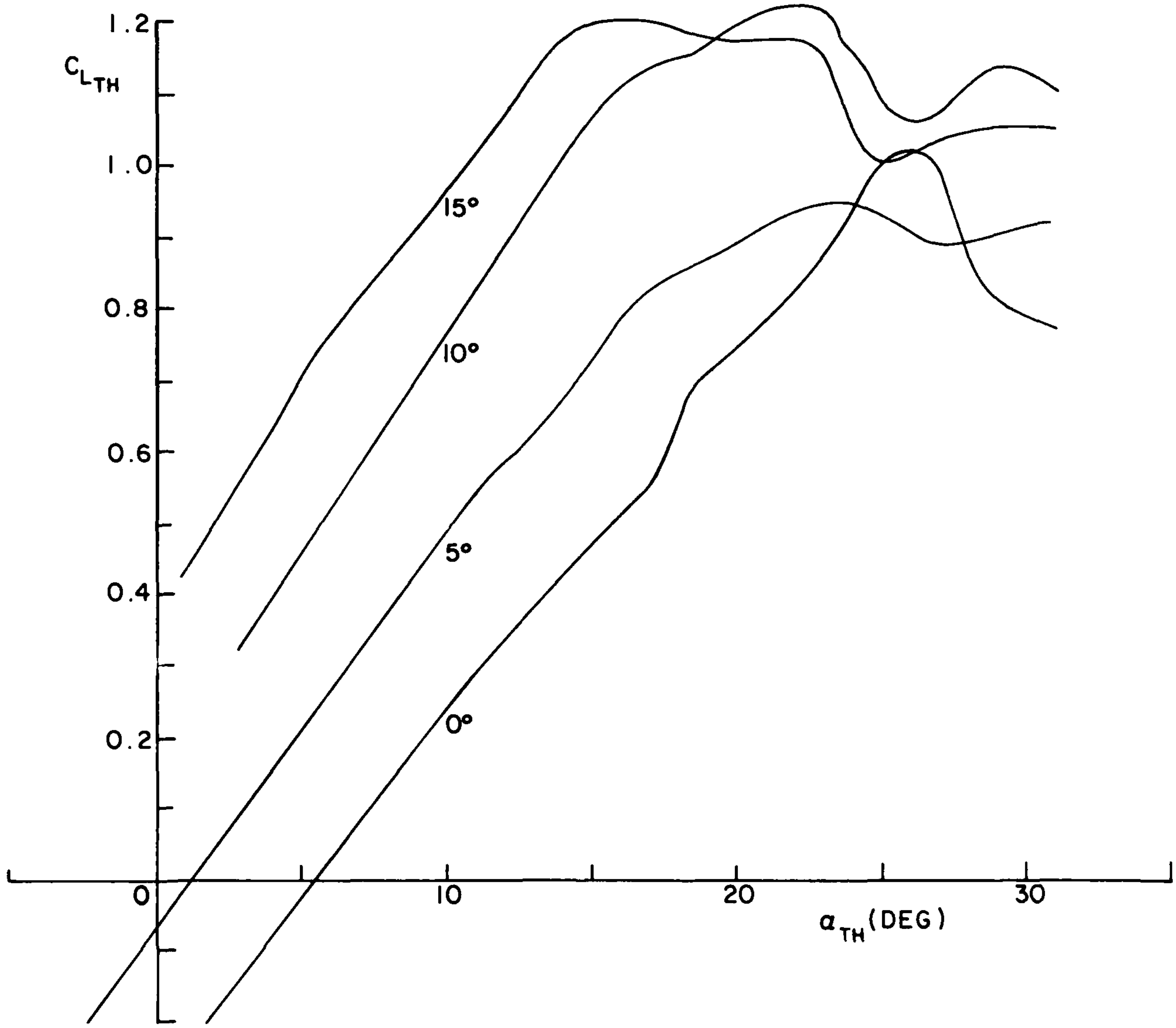

FIG. 12: $C_{L_{TH}}$ VERSUS α_{TH} FOR δ_e VARIED

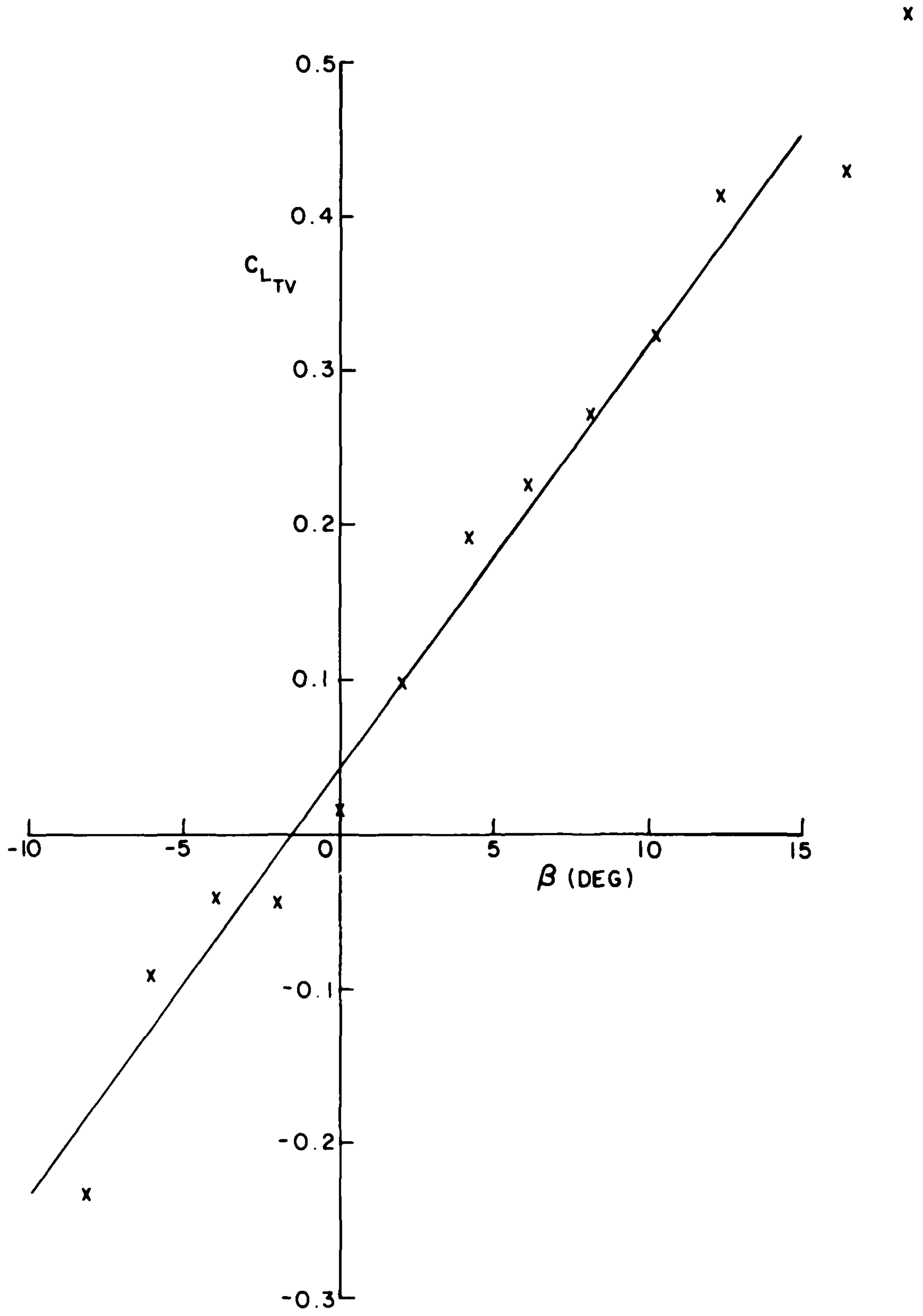

FIG. 13: $C_{L_{TV}}$ VERSUS β

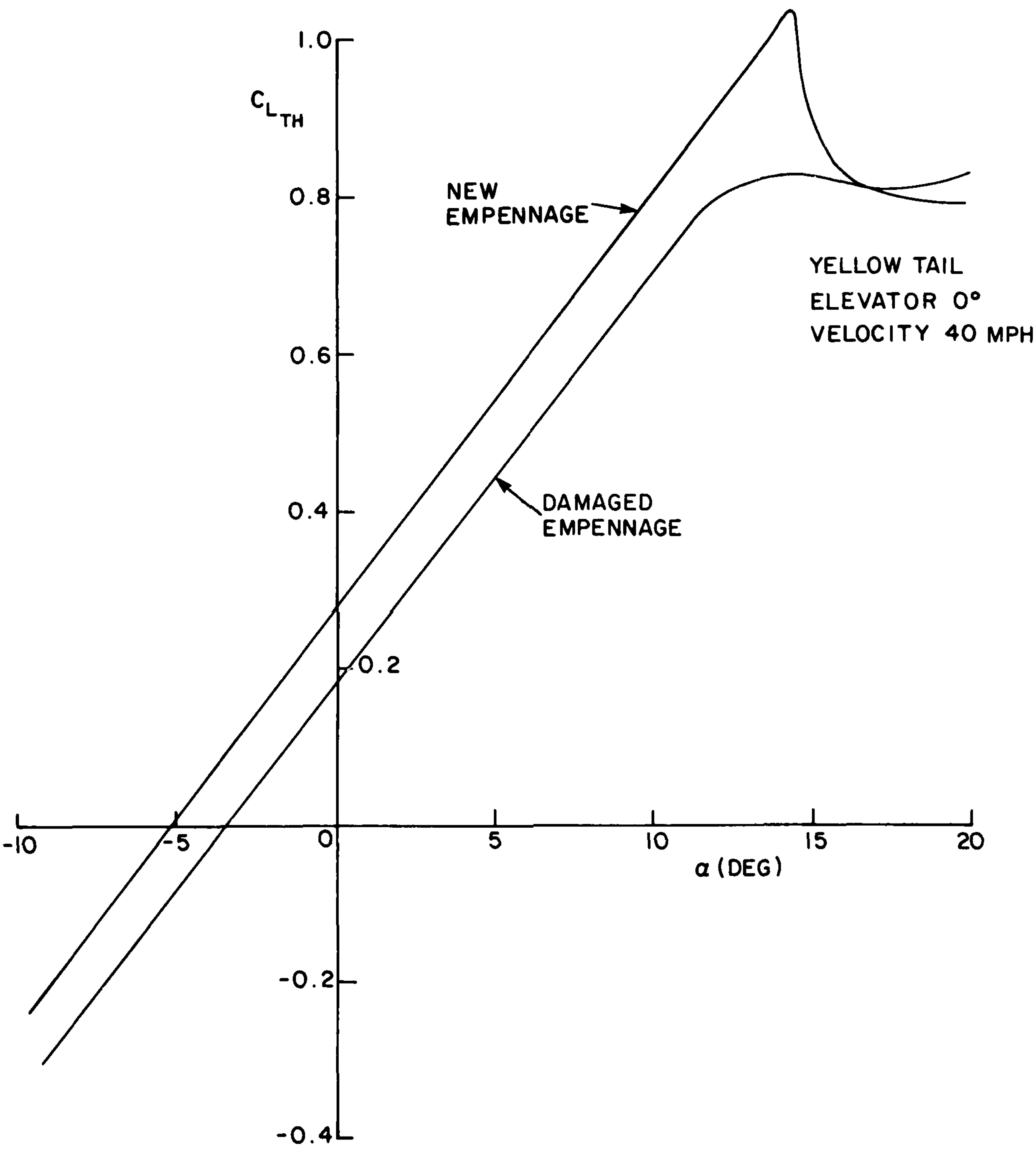

FIG. 14: DAMAGED TAIL ASSEMBLY

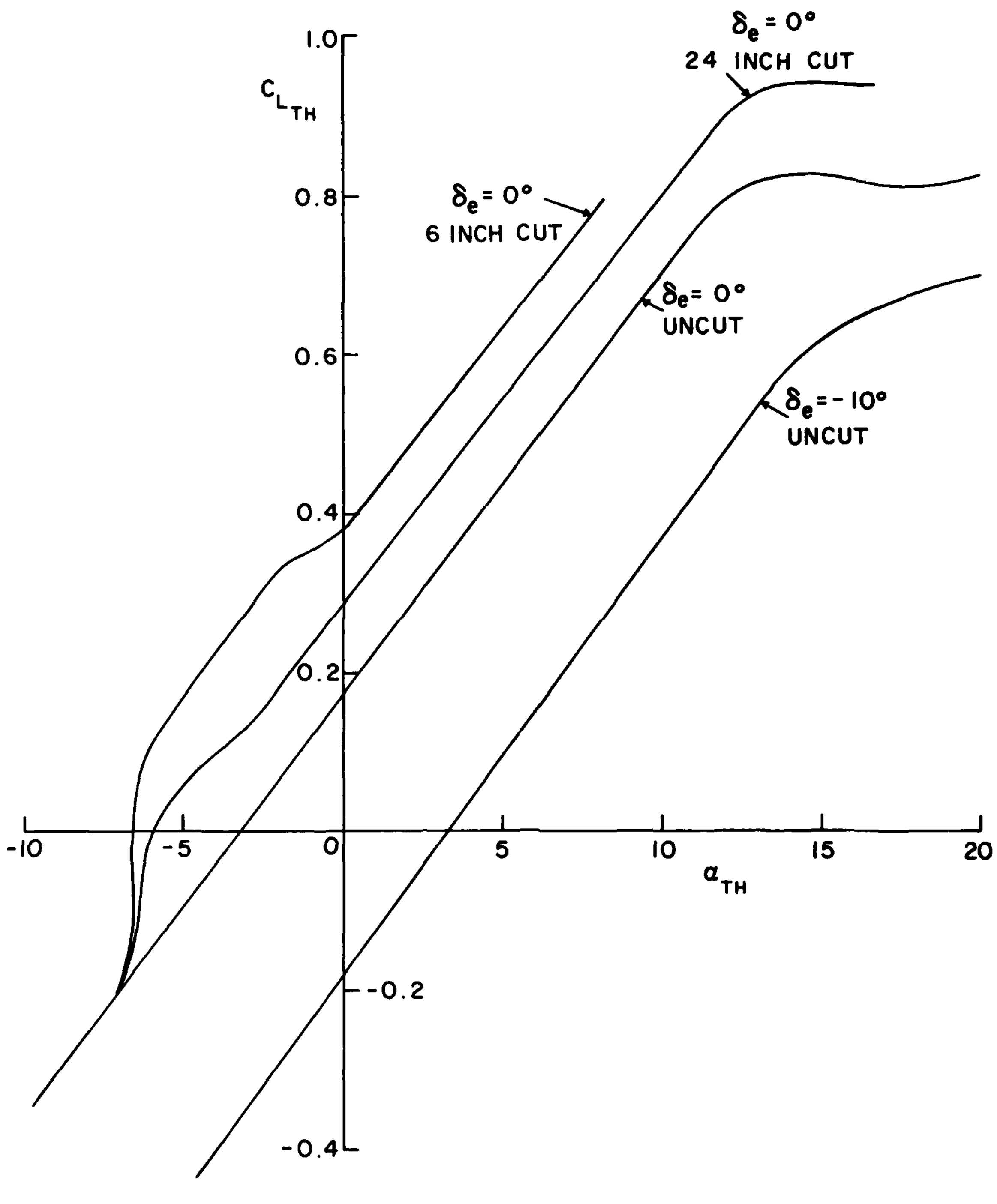

FIG. 15: CUT FABRIC $C_{L_{TH}}$ VERSUS α_{TH}

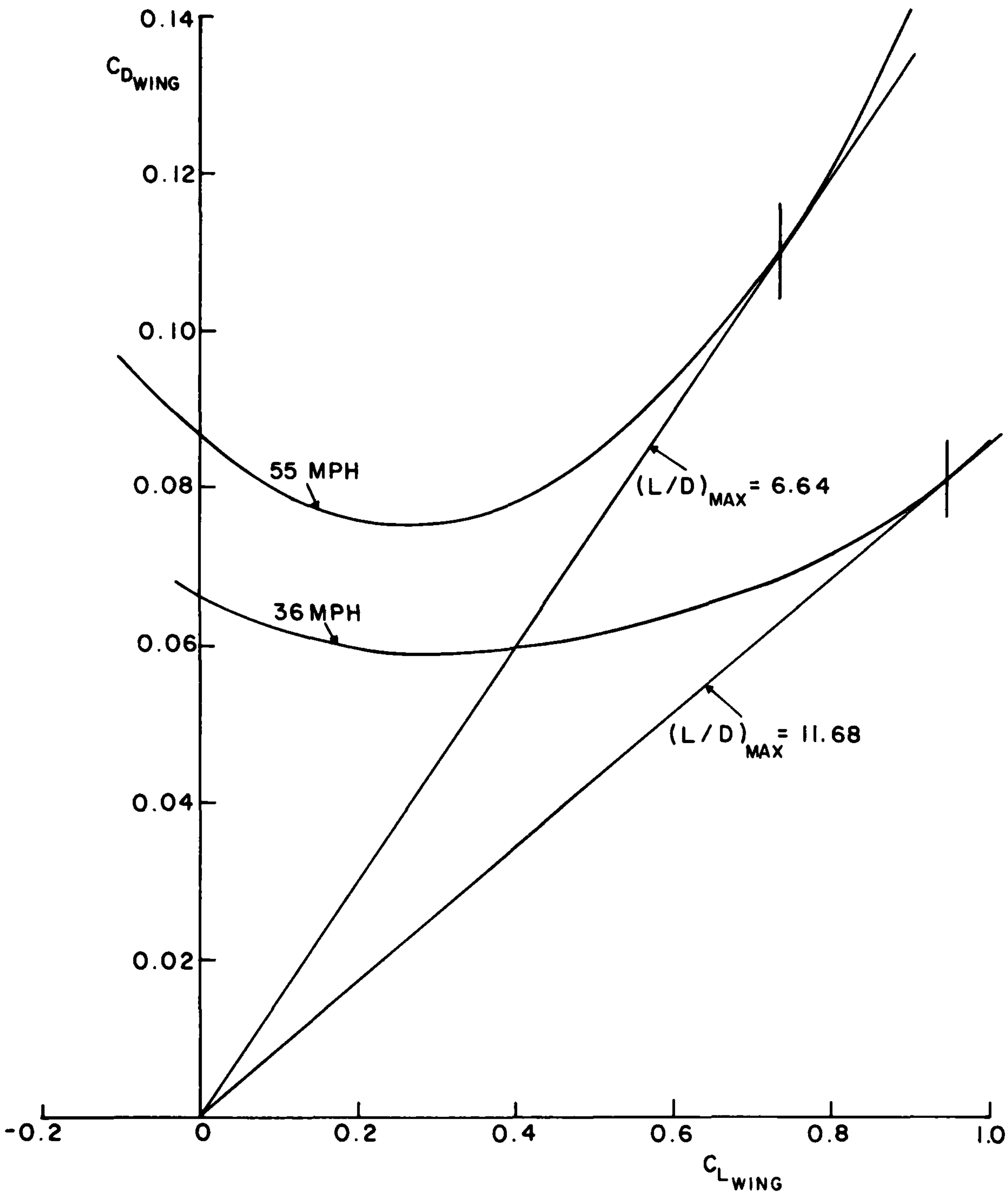

FIG. 16: EFFECT OF VELOCITY ON DRAG POLAR

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Wind Tunnel Evaluation of Chinook WT-11 Ultra Light

4

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6

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DESCRIPTORS (KEY WORDS)/MOTS-CLÉS

1. Aircraft (Birdman WT-11 Chinook)
2. Aircraft (Private)
3. Aircraft (Ultra Light) — Aerodynamic Characteristics
4. Wing Tail Configurations

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SUMMARY/SOMMAIRE

Full scale wind tunnel tests were carried out on the wing and empennage of WT-11 Chinook ultra light aircraft in the NAE 9m X 9m Low Speed Wind Tunnel. This test program was initiated in response to a request from the Canadian Aviation Safety Board, Ottawa, Ontario to determine the aerodynamics of the vehicle and measure the gross structural airloads. The purpose of the test program was to establish if there were any unusual characteristics that might have contributed to several accidents involving this design.

Aside from considerable distortion of the wing at higher dynamic pressures, corresponding to 50 to 60 mph, and considerable aeroelastic effects on lift curve slope and maximum lift coefficient, at these higher dynamic pressures the basic wing does not appear to possess any inherently dangerous characteristics. However, the empennage exhibits some non-linear characteristics that could possibly cause handling qualities problems. The combination of wing stalling characteristics with horizontal tail characteristics could result in large amplitude pitch down at the stall.

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